IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR PATENT

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TITLE: Multiple-Pass Interferometric Device

ATTY DOCKET: LMPY-9510 (255/U)

PRIORITY

This application claims the benefit of priority to United States provisional patent application no. 60/239,686, filed October 12, 2000.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to laser spectrometry, and particularly to an apparatus and method for improving the resolution of a spectrometer for measuring parameters of a laser beam.

2. Discussion of the Related Art

Semiconductor manufacturers are currently using deep ultraviolet (DUV) lithography tools based on KrF-excimer laser systems operating around 248 nm, as well as the following generation of ArF-excimer laser systems operating around 193 nm. The F_2-laser operating around 157 nm is being developed for use with Vacuum UV (VUV) photolithography.

Higher energy, higher stability, and higher efficiency excimer and molecular fluorine lasers are being developed as lithographic exposure tools for producing very small structures as chip manufacturing proceeds into the 0.10 micron regime and beyond. Specific characteristics of laser systems sought to be improved upon particularly for the lithography market include

higher repetition rates, increased energy stability and dose control, increased percentage of system uptime, narrower output emission bandwidths, improved wavelength and bandwidth accuracy, and improved compatibility with stepper/scanner imaging systems.

It is recognized herein that various components and tasks relating to today's lithography laser systems may be advantageously designed to be computer- or processor-controlled. The processors may be programmed to receive various inputs from components within the laser system, and to signal those components and others to perform adjustments such as gas mixture replenishment, discharge voltage control, burst control, alignment of resonator optics for energy, linewidth or wavelength adjustments, among others.

It is important for their respective applications to the field of sub-quarter micron silicon processing that each of the above laser systems become capable of emitting a narrow spectral band of known bandwidth and around a very precisely determined and finely adjustable absolute wavelength. Techniques for reducing bandwidths by special resonator designs to less than 100 pm for use with all-reflective optical imaging systems, and for catadioptric imaging systems to less than 0.6 pm, are being continuously improved upon. Depending on the laser application and imaging system for which the laser is to be used, line-selection and/or line-narrowing techniques are described at U.S. patent applications no. 09/317,695, 09/244,554, 09/452,353, 09/602,184, 09/599,130 and 09/629,256, each of which is assigned to the same assignee as the present application, and U.S. patents no. 5,761,236, 6,081,542, 6,061,382, 5,946,337, 6,285,701, 6,154,470, 5,095,492, 5,684,822, 5,835,520, 5,852,627, 5,856,991, 5,898,725, 5,901,163, 5,917,849, 5,970,082, 5,404,366, 4,975,919, 5,142,543, 5,596,596, 5,802,094, 4,856,018, and 4,829,536, all of which are hereby incorporated by reference. Some of the line selection and/or line narrowing techniques set forth in these patents and patent applications may be used in combination.

Techniques are also available for tuning and controlling central wavelengths of emission. Absolute wavelength calibration techniques use a known absorption, emission or level-transition line around the wavelength of

interest as a reference (see U.S. patents no. 4,905,243, 4,926,428, 5,450,207, 5,373,515, 5,978,391, 5,978,394, 6,160,832 and 4,823,354, and F. Babin et al., Opt. Lett., v. 12, p. 486 (1987), and R.B. Green et al., Appl. Phys. Lett., v. 29, p. 727 (1976), as well as U.S. patent applications no. 09/416,344 and 09/791,431 (each application being assigned to the same assignee as the present application), all of the above being hereby incorporated by reference).

The '243 patent, also mentioned above, describes the use of a monitor Fabry-Perot etalon to determine relative wavelength shifts away from the known Fe absorption lines, e.g., at 248.3271 nm and 248.4185 nm, among others. To do this, the laser wavelength is first calibrated to the absolute wavelength reference line, e.g., 248.3271 nm, and the laser beam is directed through the etalon. An interferometric image is projected onto a solid state image detector such as a CCD array. Next, the laser wavelength is tuned away from the 248.3271 nm line to a new wavelength. A new image is projected onto the detector, and a comparison with the original image reveals the new wavelength because the free spectral range (FSR) of the monitor etalon is presumably known (e.g., 9.25 pm). For example, if it is desired to tune the laser to 248.3641 nm, then the wavelength would be adjusted 37 pm above the 248.3271 nm Fe vapor absorption line to exactly coincide with four FSRs of the monitor etalon.

Other optical characteristics of a laser beam that are desired to know and control are the bandwidth and spectral purity. The bandwidth can be measured as the full width at half maximum (FWHM) of a spectral intensity distribution of a measured laser pulse. The spectral purity is determined as the spectral range within which lies 95% of the energy of the laser pulse.

The bandwidth of a radiation source used, e.g., in photolithographic applications, is constrained by its effect on imaging resolution due to chromatic aberrations in optics of catadioptric imaging systems. The bandwidth of a laser beam can be determined from measuring the widths of fringes produced as the laser beam is passed through a monitor etalon and projected onto a CCD array. A grating spectrometer may also be used and the bandwidth measured in a similar fashion (see U.S. patents no. 5,081,635